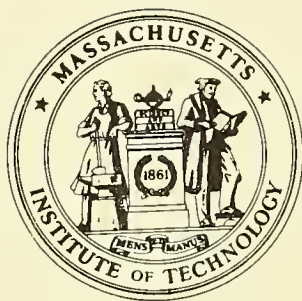



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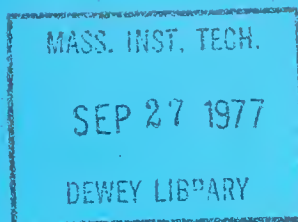
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A REGIONAL ECONOMIC POLICY SIMULATION MODEL

George Treyz  
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Working Paper No. 202

June 1977

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## I. Introduction and Overview

The need for accurate and comprehensive regional policy models has been heightened by increasing concern with the differential regional economic effects of national fiscal, energy, environmental, welfare, and other policies, and with the attempts of state and local governments to mitigate the effects of economic and fiscal decline and to promote industrial growth. The greatest need is for models that are explicitly sensitive to the differential changes in regional production costs, which might be caused by alternative tax policies, energy price structures, pollution abatement requirements, changes in transfer payment flows, and the like.

In order to meet this need adequately, a regional policy model should fulfill the following criteria:

1. It should be able to measure the extent to which both policy-determined and uncontrolled changes affect the costs of production in a region, and, in turn, how such changes affect the comparative advantage of the region as a location for export activities. In other words, the model should be able to quantify the effects of cost changes on the region's economic base through their influence on regional production levels and the location of those industries that serve extra-regional markets. Although some existing industrial location models fulfill this criterion they do not fulfill the next two.

2. The model should be able to show how changes in input prices either internal or external to the region, will affect relative factor and intermediate input intensities in regional production. This criterion is fulfilled much more often by regional econometric models, which are generally based on classical production theory, than by most regional input-output models, which ordinarily assume that input coefficients are immutable, except in the very long run.

3. The model should be able to gauge accurately the regional indirect effects of changes in basic export activity levels on those activities that supply goods and services to production and final consumption within the region. The calculation of

these economic base multiplier effects is an integral part of most regional input-output models. However, most regional econometric models calculate only the induced effects generated through changes in household income and consumption without giving appropriate consideration to the indirect effects generated by intra-regional input-output relationships between export and local activities and among local activities themselves.

The model described in this paper fulfills the three foregoing criteria by combining the econometric modeling efforts of Friedlaender et al (1975) and Glickman (1977) with the economic base and regional input-output approaches of Isard (1960), Tiebout (1962), Bourque et al (1967), and Miernyk (1970), and the comparative cost location theory of Weber (1928), Hoover (1937), and Isard (1956). The major contribution of previous econometric models to the present work lies in the derivation of the labor demand equations from the neo-classical theory of the firm and in the consideration of macroeconomic ties between the national and regional economies. Regional input-output analysis and economic base theory form the basis for the model's emphasis on the indirect and induced intra-regional employment impacts of changes in both export and local economic activity. Classical location theory provides comparative cost analysis in which the distribution among regions of production in national-market industries is determined by the relative production costs and wherein locational shifts among regions are the result of changes in these relative costs. The model also reflects some of the work of Borts and Stein (1964) on regional variations in factor shares and interregional migration of persons and production in an open economy.

Some previous regional and multi-regional models **that** are sensitive to selected policy impacts on costs are worth mention. For example, Harris (1974) and Olsen (1977) consider the effects of fuel price and transport system changes on costs, cost changes on industrial shifts, and the secondary effects of such shifts on the economies of each of an entire system of interdependent regions. But as Glickman (1977) points out, most regional models make implicit what Klein (1969) felt should be specified

explicitly: namely, the dependence of the region's export base on regional prices relative to those of the rest of the nation. In addition many of the models do not allow for factor substitution.

The model presented here, while it meets both the objectives and objections raised above, is under further development. The present form of the employment demand equations, and their underlying theoretical foundations, are presented in Section II, Section III provides an example of the quantitative implementation of the equations and an analysis of the direct partial equilibrium effects of exogenous tax rate changes. Section IV sets forth a complete model that incorporates these equations and demonstrates it with a sample dynamic policy simulation. Section V provides a brief summary and conclusions. An Appendix contains the derivations of the factor cost expressions.

## II. A Model of Regional Employment Demand

The assumptions upon which the model is based are straightforward:

1. Firms seek to maximize profits.
2. The regional and national production processes of the  $i^{\text{th}}$  industry are the same and can be described by a Cobb-Douglas production function with constant returns to scale and factor neutral technical change.
3. The marketing advantage of local production for local use is sufficiently strong and stable that the proportion of the regional use of the  $i^{\text{th}}$  commodity that is supplied from local production will remain constant, at least over the forecast period, even if there are changes in relative regional production costs.
4. The distribution among regions of the production of the goods and services which supply extraregional demands will respond to changes in relative production costs.

While the first assumption has periodically been questioned by believers in the behavioral theory of the firm,<sup>1</sup> it is a well accepted neoclassical postulate that does not need to be defended. The second assumption is somewhat less tenable, particularly in view of the recent work of Jorgensen and others (1973), which questions the separability postulate implied by a Cobb-Douglas or similar production function.

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<sup>1</sup>See, for example, Marris (1964).

Nevertheless, the Cobb-Douglas production function has received considerable empirical support,<sup>2</sup> and appears to be a reasonably accurate characterization of production. Finally, while there is abundant evidence that factor prices and intensities vary across the nation, there is little reason to believe that basic technology differs markedly among regions.

The assumption that a constant proportion of local demand for each good or service will be supplied from local production does not seem unreasonable. A region tends to have a strong comparative advantage in the supplying of local needs, though this advantage varies widely with the type and transportability of the product. Thus, for example a large proportion of local demand for personal services would be supplied by each region to itself; as a consequence personal services should be a minor export or import of most regions. In any case, constancy of the proportion supplied from local production, at least over the course of a model run, is a necessary assumption if the model is to be of acceptable complexity.

Finally, the assumption that the region's export share of national production responds to changes in relative regional costs reflects the "foot-loose" nature of most export activity. Thus, while local production of many goods and services dominate the local market, export production competes in a national market and will move to locations which provide increased profits, simulated here by reduced costs.

Using these four assumptions, it is possible to develop expressions for local and export production. These reflect the interrelationships among local demand, local production and input costs.

The basic identity in the model is:

$$E_i = E_i^L + E_i^X \quad (1)$$

where:

$E_i$  = total regional employment in sector i

$E_i^L, E_i^X$  are the local-serving and export employments in industry i respectively.

#### A. Local-Serving Employment

Regional non-export output is used not only for final consumption, but also as an input to other regional industries. Thus one can write:

$$E_i^L = \sum_j e_{ij} E_j + \sum_h d_{ih} D_h \quad (2)$$

<sup>2</sup>Griffen and Gregory (1976) have recently shown that the Cobb-Douglas production function provides a good characterization of substitutability between fuel and other inputs.

where:

$e_{ij}$  = the number of regional employees required in the  $i^{th}$  industry for each regional employee in the  $j^{th}$  industry.

$d_{ih}$  = the number of regional employees required in the  $i^{th}$  industry for each regional unit of demand in the  $h^{th}$  final demand sector;

$D_h$  = the regional final demand in the  $h^{th}$  sector.

# 1. The Interindustry Employment Coefficients ( $e_{ij}$ )

While the  $e_{ij}$  coefficients are an obvious analog to the familiar input-output coefficients, they are made somewhat more complicated by three factors: (1) they refer to employment rather than output; (2) they relate to employment in production for local use rather than total regional production; and (3) data are not available to estimate them directly.

In deriving and estimating the  $e_{ij}$  coefficients, we begin by defining total regional output for industry  $i$  as  $X_i$ . Then

$$e_i \equiv E_i / X_i \quad (3)$$

represents the labor/output ratio in industry  $i$ . Following familiar input-output terminology, if  $X_{ij}$  represents the total shipments of industry  $i$  to industry  $j$ , then define:

$$E_{ij} \equiv e_i X_{ij} \quad (4)$$

Since however,

$$a_{ij} \equiv X_{ij} / X_j \quad (5)$$

represents the amount of input from industry  $i$  per unit output of industry  $j$ ,

$$e_{ij}^* \equiv (e_i)(a_{ij}) = \left(\frac{E_i}{X_i}\right)\left(\frac{X_{ij}}{X_j}\right) \quad (6)$$

represents the amount of labor in industry  $i$  needed per unit output in industry  $j$ .

Then,

$$e'_{ij} = \left(\frac{e_i}{e_j}\right)(a_{ij}) \equiv \left(\frac{E_i}{X_i}\right)\left(\frac{X_{ij}}{X_j}\right)\left(\frac{X_j}{E_j}\right) \quad (7)$$

represents the amount of labor in industry  $i$  needed per unit of labor in industry  $j$ . It is important to note that  $e'_{ij}$  is not fixed because  $e_i$ ,  $e_j$  and  $a_{ij}$  can vary with changes in relative factor prices and technology.

Finally, since not all of each input  $i$  is purchased within the region, the relationship is modified to:

$$e_{ij} = (e'_{ij})\rho_i \quad (8)$$

where  $\rho_i$  is defined as the regional purchase coefficient for  $i$  and represents the proportion of regional use of the  $i^{\text{th}}$  commodity that is supplied from local production.

Although it is not possible to estimate the  $e'_{ij}$  directly, it is possible to estimate each term in the following expression:

$$e'_{ij} = k_{ij} \cdot \ell_i \cdot E_i^u/E_j^u \cdot b_{ij} \quad (9)$$

where:

$k_{ij}$  = the proportion of the  $i^{\text{th}}$  sector's output that is delivered to the  $j^{\text{th}}$  sector as shown in the most recent national input-output flow table; this is,  $k_{ij} = X_{ij}^u/X_i^u$ , where the superscript  $u$  represents national variables;

$\ell_i$  = the regional labor intensity relative to the national labor intensity for the  $i^{\text{th}}$  sector: that is,  $\ell_i = (E_i/X_i)/(E_i^u/X_i^u)$ ;

$E_i^u, E_j^u$  = national employments in the  $i^{\text{th}}$  and  $j^{\text{th}}$  sector, respectively.

$b_{ij}$  = the regional materials/labor ratio for input  $i$  in industry  $j$  relative to that of the nation: that is,  $b_{ij} = (X_{ij}/E_j)/(X_{ij}^u/E_j^u)$ .

The identity between equations (7) and (9) can be shown by simple substitution, therefore it is sufficient to show that the terms in equation (9) can be estimated.

Since data on regional output and materials inputs ( $X_{ij}$  and  $X_i$ ) are not available,  $\ell_i$  and  $b_{ij}$  cannot be estimated directly. However, it is possible to derive estimable expressions for these terms from the cost function associated with the Cobb-Douglas production function.

If the technology of every industry can be characterized by a CRS Cobb-Douglas function, then:

$$X_j = \theta_j (E_j)^{\lambda_{Lj}} (K_j)^{\lambda_{Kj}} (F_j)^{\lambda_{Fj}} \prod_{i=1}^n (X_{ij})^{\lambda_{ij}} \quad (10)$$

where  $\theta_j$  represents a neutral technical change factor;  $E_j, K_j$  and  $F_j$  respectively represent the labor, capital, and energy inputs into industry  $j$ ;  $\sum \lambda_{sj} = 1$ , where  $s$  ranges over all material inputs; and  $X_{ij}$  is as previously defined.

It is straightforward to derive the following cost-function from this production function:

$$C_j = \theta_j \left( \frac{w_j}{\lambda_{Lj}} \right)^{\lambda_{Lj}} \left( \frac{c_j}{\lambda_{Kj}} \right)^{\lambda_{Kj}} \left( \frac{f_j}{\lambda_{Fj}} \right)^{\lambda_{Fj}} \prod_{i=1}^n \left( \frac{y_{ij}}{\lambda_{ij}} \right)^{\lambda_{ij}} X_j \quad (11)$$

where  $w_j, c_j, f_j$  and  $y_{ij}$  respectively represent the labor, capital, energy and materials cost to industry  $j$ . Since the demand function for any given factor can be obtained by differentiating the cost function with respect to its price, the demands for labor and any material input  $i$  are respectively given by:

$$E_j = \lambda_{ij} \theta_j \left( \frac{w_j}{\lambda_{Lj}} \right)^{\lambda_{Lj}-1} \left( \frac{c_j}{\lambda_{Kj}} \right)^{\lambda_{Kj}} \left( \frac{f_j}{\lambda_{Fj}} \right)^{\lambda_{Fj}} \prod_{i=1}^n \left( \frac{y_{ij}}{\lambda_{ij}} \right)^{\lambda_{ij}} X_j \quad (12)$$

$$X_{ij} = \lambda_{ij} \theta_j \left( \frac{w_j}{\lambda_{Lj}} \right)^{\lambda_{Lj}} \left( \frac{c_j}{\lambda_{Kj}} \right)^{\lambda_{Kj}} \left( \frac{f_j}{\lambda_{Fj}} \right)^{\lambda_{Fj}} \prod_{\substack{s=1 \\ s \neq j}}^n \left( \frac{y_{sj}}{\lambda_{sj}} \right)^{\lambda_{sj}} \left( \frac{y_{ij}}{\lambda_{ij}} \right)^{\lambda_{ij}-1} X_j \quad (13)$$

Since it is assumed that the production function does not vary across regions, similar expressions for  $E_j^u$  and  $X_{ij}^u$  can be derived. Dividing  $E_j$  by  $E_j^u$  and  $X_{ij}$  by  $X_{ij}^u$ , yields:

$$\frac{E_j}{E_j^u} = \left( \frac{w_j}{w_j^u} \right)^{1-\lambda_{Lj}} \left( \frac{c_j}{c_j^u} \right)^{\lambda_{Kj}} \left( \frac{f_j}{f_j^u} \right)^{\lambda_{Fj}} \prod_{i=1}^n \left( \frac{y_{ij}}{y_{ij}^u} \right)^{\lambda_{ij}} \left( \frac{X_j}{X_j^u} \right) \quad (12a)$$

$$\frac{X_{ij}}{X_{ij}^u} = \left( \frac{w_j}{w_j^u} \right)^{\lambda_{Lj}} \left( \frac{c_j}{c_j^u} \right)^{\lambda_{Kj}} \left( \frac{f_j}{f_j^u} \right)^{\lambda_{Fj}} \prod_{i=1}^n \left( \frac{y_{sj}}{y_{sj}^u} \right)^{\lambda_{sj}} \left( \frac{y_{ij}}{y_{ij}^u} \right)^{\lambda_{ij}-1} \left( \frac{X_j}{X_j^u} \right) \quad (13a)$$

Solving 12a for  $(E_j/X_j)/(E_j^u/X_j^u)$  it is easy to obtain:

$$\ell_i' = \left( \frac{E_j}{X_j} \right) \left( \frac{E_j^u}{X_j^u} \right)^{-1} = \left( \frac{w_j}{w_j^u} \right)^{1-\lambda_{Li}} \left( \frac{c_j}{c_j^u} \right)^{\lambda_{Ki}} \left( \frac{f_j}{f_j^u} \right)^{\lambda_{Fi}} \prod_{j=1}^n \left( \frac{y_{ij}}{y_{ji}^u} \right) \quad (14)$$

Since the  $\lambda$  coefficients of a CRS Cobb-Douglas production function are given by the factor shares,  $\ell_i'$  can be estimated directly from observable data on factor and input prices and the expenditure shares.<sup>3</sup> However, because the cost function is based on cost-minimizing behavior,  $\ell_i'$  represents the equilibrium relative intensities

<sup>3</sup>Data are not available for  $y_{ij}$  on a regional basis. However, by assuming that all industries pay the same price for any material input (i.e.,  $y_{ij} = y_{is}$  for all  $j$  and  $s$ ) the problem can be made tractable. The appendix gives the formal derivation of the factor prices and material input prices.

of the region and the nation. Since adjustments do not occur instantaneously, a moving average of past  $l_i^t$  is used to estimate the actual relative labor intensities,  $l_{it}$ , in the  $t^{th}$  period.

Similarly, dividing equation 13a by equation 12a gives:

$$b'_{ij} \equiv \left( \frac{X_{ij}}{E_j} \right) / \left( \frac{X_{ij}^u}{E_j^u} \right) = \left( \frac{w_j}{y_i} \right) / \left( \frac{w_j^u}{y_i^u} \right) \quad (15)$$

Again, since equilibrium does not occur instantaneously, a moving average of  $b'_{ij}$  is used to estimate the actual ratio of materials for  $i$  to labor for  $j$  in the  $t^{th}$  period,  $b_{ij,t}$ .

Having obtained expressions for  $l_i$  and  $b_{ij}$ , it is now possible to estimate the  $e'_{ij}$  coefficients, which give the amount of employment in industry  $i$  needed per unit of employment in industry  $j$  from Equation (9). To estimate regional employment, we then multiply  $e'_{ij}$  by  $\rho_i$ .

## 2. The Final Demand Coefficients ( $d_{ih}$ )

As explained above,  $d_{ih}$  represents the local employment in industry  $i$  per unit of final demand in sector  $h$ , and is derived as follows. Let  $X_{ih}$  represent the shipments of industry  $i$  to final demand sector  $h$  and  $D_h$  represent the final demand of sector  $h$ . Then,

$$\delta_{ih} = \frac{X_{ih}}{D_h} \quad (16)$$

represents the final goods shipments of industry  $i$  per unit of final demand in sector  $h$ . Since  $e_i \equiv E_i/X_i$  represents the employment per unit output of industry  $i$ ,

$$d'_{ih} \equiv e_i \delta_{ih} \quad (17)$$

represents the employment in industry  $i$  per unit of final demand before adjustment for regional import patterns. Unfortunately, data are not available to estimate  $\delta_{ih}$  on a regional basis, although they are available on a national basis. If one is willing to assume, however, that the composition of each final demand sector does not vary across regions, then  $\delta_{ih} = \delta_{ih}^u$  and  $X_{ih}/D_{ih} = X_{ih}^u/D_h^u$ . It is then possible to

estimate  $d'_{ih}$  by the following expression:

$$d'_{ih} = k_{ih} \cdot \ell_i \cdot E_i^u / D_h^u \quad (18)$$

where

$k_{ih}$  = the national shipments of industry  $i$  per unit of final demand sector  $h$ , that is,  $k_{ih} = X_{ih}^u / D_h^u$ ;

$\ell_i$  = the regional labor intensity relative to that of the nation, that is,  $\ell_i = (E_i / X_i) / (E_i^u / X_i^u)$ ;

$E_i^u$  = national employment in industry  $i$ ;

$D_h^u$  = national final demand in sector  $h$ .

Finally, since all of the regional final demands are not supplied from local production,  $d'_{ih}$  must be adjusted by the regional purchase coefficient. Thus:

$$d_{ih} = d'_{ih} \rho_i \quad (19)$$

### 3. The Regional Purchase Coefficients ( $\rho_i$ )

In deriving the local employment in industry  $i$ , adjustments were made for actual production and purchase patterns through the application of  $\rho_i$ . These regional purchase coefficients merely reflect the fact that a region is an open economy. Goods and services for production inputs or to serve final demand will be imported, rather than produced locally, to the extent that regional comparative costs and product transportability warrants. The regional employment coefficients must be reduced to reflect this "leakage" of purchases typical of an open economy.

Regional purchase coefficients have been developed and estimated by Stevens et al (1975)(1977) in order to evaluate accurately regional economic effects and disaggregated local multipliers in regional input-output impact studies. In the somewhat different form used here,

$$\rho_i = (S_i)(X_i / U_i) \quad (20)$$

where

$S_i$  = the proportion of the  $i^{th}$  regional output shipped less than 100 miles;

$X_i$  = regional production of commodity i.

$U_i$  = regional use of commodity i.

The variables  $S_i$  is a direct estimate of the proportion of regional production of good i that stays within the region. This is not, of course, the same thing as the proportion of intermediate and final demand for i to be supplied by the region. The latter depends also on relative supply and demand of i by activities in the region, defined here by  $X_i/U_i$ .

The general interpretation of the ratio  $X_i/U_i$  is quite straightforward. The larger the production of a good or service in a region relative to its internal use, the more likely that any particular purchase of the product as an input to production or to fulfill final demand in the region will be made locally. Thus a sector which is capable of being a net exporter ( $X_i/U_i > 1$ ) should have a high regional purchase coefficient and vice versa.

Even for levels of  $X_i/U_i$  greater than one, however,  $\rho_i$  may be less than 1 if  $S_i$  is small enough. The latter case suggests an industry whose product is simultaneously exported and imported. This is a reasonable possibility, especially since at the 2-digit level each product sector is an admixture of several products. It would be surprising if all of the individual products which make up a sector's output would be produced in a region (in the right relative proportions) even when the region has a large relative output in the sector.

Data are not available to measure  $X_i/U_i$  directly. However, this ratio can be determined indirectly. Define the ratio of regional to national use as:

$$\frac{U_i}{U_i^u} = \sum_j k_{ij} \frac{X_{ij}}{X_{ij}^u} + \sum_h k_{ih} \frac{D_h}{D_h^u} \quad (21)$$

Then it is possible to obtain  $X_{ij}/X_{ij}^u$  from equation (15a) and  $X_i/X_i^u$  from equation (14). Using these values, write:

$$\frac{X_i}{U_i} = \left( \frac{X_i}{X_i^u} \right) / \left( \frac{U_i}{U_i^u} \right) \quad (22)$$

In order for this equality to hold exactly it is sufficient to assume that the nation has zero net exports<sup>4</sup> in each sector ( $X_i^u = U_i^u$ ). The  $\rho_i$  values calculated using (22) and (20) are then used in equations (8) and (19) above to obtain local employment in each sector.

#### B. Export Employment

It is assumed that the share of national production produced by the region for export to other regions responds to relative production costs. Thus, we can write:

$$\frac{X_i^x}{X_i^u} = \gamma_i P_i^{\epsilon} + r_i \quad (23)$$

where:

$P_i$  represents production costs in the region relative to the nation

$\gamma_i$  and  $\epsilon_i$  are coefficients to be estimated

$r_i$  represents an additive error term.

From Equation (14),

$$\frac{X_i}{X_i^u} = \frac{E_i}{E_i^u} \cdot \frac{1}{\rho_i} \quad (24)$$

Since, however, production is subject to constant returns to scale, we can allocate local and export production to local and export inputs. Thus,<sup>5</sup>

<sup>4</sup>Alternatively it can be assumed that the proportion of each sector's output which goes to foreign sales is the same for the region as for the nation.

<sup>5</sup>If production is divided into outputs for local use and for export, and inputs are allocated accordingly, one can write:

$$X_i^x = E_i^x \prod_{j=1}^n x_{ji}^{\lambda_{ji}} - K_i^x \prod_{j=1}^n x_{ji}^{\lambda_{ji}} - F_i^x \prod_{j=1}^n x_{ji}^{\lambda_{ji}}$$

where the superscript x denotes production for export. Deriving the cost function from this expression, and dividing the resulting demand function for  $E_i^x$  by the national labor demand equation, yields equation (25).

$$\frac{X_i^x}{X_i^u} = \frac{E_i^x}{E_i^u} \frac{1}{l_i} \quad (25)$$

Substituting Equation (25) into Equation (23) then yields

$$\frac{E_i^x}{E_i^u l_i} = \gamma_i P_i^\epsilon + r_i \quad (26)$$

Since we want to explain the number of export employees in any given industry, however, it is not desirable to estimate Equation (26) directly by simply pooling all industries because this would give equal weights to large and small industries. Therefore, we multiply both sides of Equation (26) by the mean values of the products of  $E_i^u$  and  $l_i$  over the sample period to act as a scaling factor, and estimate:

$$\frac{E_i^x}{E_i^u l_i} \cdot \bar{E}_i^u \bar{l}_i = \beta_i P_i^\epsilon + u_i \quad (26a)$$

where  $\beta_i = \gamma_i \bar{E}_i^u \bar{l}_i$  and  $u_i = r_i \bar{E}_i^u \bar{l}_i$

The variable  $P_i$  represents the average cost of producing  $X_i$  in the region relative to the average production costs in the nation. From the cost function given in Equation (11) above, it is straightforward to obtain:

$$P_i' \equiv \left( \frac{C_i}{X_i} \right) / \left( \frac{C_i^u}{X_i^u} \right) \\ = \left( \frac{w_i}{w_i^u} \right)^{\lambda_{Li}} \left( \frac{c_i}{c_i^u} \right)^{\lambda_{Ki}} \left( \frac{f_i}{f_i^u} \right)^{\lambda_{Fi}} \prod_{i=1}^n \left( \frac{y_i}{y_i^u} \right)^{\lambda_{ij}} \quad (27)$$

where all the variables have been defined in Equation (11).

Since, however, equilibrium does not occur instantaneously, lags of adjustment must be taken into account, and thus define  $P_i$  as:

$$P_i = \sum_{h=1}^g \frac{1}{g} P_{i,t-h}' \quad (27a)$$

where  $g$  represents the length of the average time required to return to a locational equilibrium and is an estimated parameter.<sup>6</sup>

<sup>6</sup> Because  $g$  is an estimated parameter and  $u_i$  is additive Equation (23) requires a non-linear estimation technique.

III. A Quantitative Implementation of the Employment Equations and an Analysis of the Direct Partial Equilibrium Static Effects of Tax Rate Changes.

The regional employment equation structure for Massachusetts has been estimated using quarterly data from the first quarter of 1954 through the third quarter of 1975. The above specification was used without modification for 23 employment sectors.<sup>7</sup> It was also used, with the exception of the export term, for contract construction and transportation and utilities. Alternative specifications based on real government expenditures were used for three government sectors.

Local-serving employment was obtained by substituting the relevant expressions in equation (2). Some of the required parameters<sup>8</sup> are shown on Table 1.

Having obtained the export-serving employment via the identity in equation (1) the estimated parameter values that were found by minimizing sample period squared export employment error over all industries were: (1) the location responses of export production to changes in Massachusetts costs relative to those in the nation ( $\epsilon$ ); (2) the length of the location response time ( $g$ ); and (3) the relationship of the Massachusetts share of export production to demand for export employment ( $\gamma_i$ ) when the location elasticity is  $\epsilon$ . This is, the squared error of employment, summed over both 23 sectors and over the 35 periods available, was expressed as a function of  $\epsilon$ ,  $g$ ,  $\gamma_i$  and the values of  $\epsilon$ ,  $g$ , and  $\gamma_i$  that minimized this function (see equation 26a) were determined. The length of the location response period ( $g$ ) and the elasticity of location response ( $\epsilon$ ) that minimized the squared error of the equation were respectively 5 years and -4.28. On the basis of the reduction in squared error, the elasticity estimate ( $\epsilon$ ) was significantly different from zero at the one percent level.

Table 1 gives the following information for each industry: the proportion of total employment which is export dependent, the regional purchase coefficient, the labor share and capital share, and the proportion of

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<sup>7</sup>See Table 1 or 4 below for a list of the employment sectors.

<sup>8</sup>See Treyz et al (1977) pages 37-39 for all of the parameters. The labor intensity terms ( $l_{i,t}$ ) uses a thirteen year moving average to reflect embodied technology for the average lifetime of manufacturing equipment.

Table 1

## Selected Employment Sector Parameters

	Regional Purchase Coefficient	$\hat{\gamma}_i$	Proportion of Employment Dependent On Exports 1977:1	Proportion of the ith Sectors Costs Attributable To		Proportion of Output that goes to Consumption and Government Demand
	$\rho_i$			<u>Labor</u> $\lambda_{Li}$	<u>Capital</u> $\lambda_{K,i}$	$(D_i)$
<u>Manufacturing</u>						
<u>Durables</u>						
Ordinance(19)	.63	.053	.87	.40	.18	.92
Lumber (24)	.09	.006	.62	.48	.22	.04
Furniture (25)	.25	.016	.68	.45	.15	.60
Stone, Clay, etc. (32)	.41	.013	.49	.48	.19	.06
Primary Metals(33)	.17	.008	.62	.42	.19	.01
Fabricated Metals (34)	.28	.019	.75	.31	.13	.06
Non-elec Machines (35)	.33	.030	.83	.32	.15	.09
Elec. Equip.(36)	.14	.043	.92	.41	.15	.47
Trans. Equip. (non-M.V.)(370)	.03	.017	.95	.33	.15	.57
Motor V. & Parts (371)	.01	.007	.96	.30	.14	.60
Instruments(38)	.28	.066	.91	.41	.26	.34
<u>Non-Durables</u>						
Food(20)	.36	.010	.37	.22	.11	.93
Textiles(22)	.31	.027	.62	.38	.14	.16
Apparel(23)	.36	.030	.70	.38	.11	.92
Paper(26)	.65	.025	.49	.42	.19	.12
Printing(27)	.52	.022	.55	.44	.18	.28
Chemicals(28)	.19	.013	.65	.29	.25	.38
Rubber(30)	.55	.039	.65	.44	.16	.23
Leather(31)	.68	.123	.74	.57	.21	.89
Other Durables(39)	.56	.052	.72	.48	.21	.57
<u>Non-Manufacturing</u>						
Contract Const.(c)	1.00			.38	.05	.33
Transport & Utilities(R)	.74			.42	.29	.48
Wholesale & Retail Trade(T)	1.00	.003	.05	.63	.13	.74
Finance, Ins. & Real Estate(FIR)	1.00	.005	.07	.35	.43	.74
Service & Misc. (SV&)	1.00	.008	.20	.49	.06	.61

output that goes to consumption and final demand.<sup>9</sup>

By differentiating the employment equation<sup>10</sup> with respect to relative production costs, relative labor intensity, and the relative price level of output, it is straightforward to obtain the following expression:

$$\hat{E}_i = \sigma_i^x \epsilon \hat{P}_i + \hat{\ell}_i - (1 - \sigma_i^x)(1 - D_i) \hat{Y}_i \quad (28)$$

where

$\sigma_i^x$  = the export share

$\epsilon$  = the elasticity of location response to regional costs.

$\hat{P}_i$  = the percentage change in relative regional costs.

$\hat{\ell}_i$  = the percentage change in relative regional labor intensity.

$D_i$  = the percent of local output going to final demand.

$\hat{Y}_i$  = the percentage change in the regional price of the  $i^{\text{th}}$  commodity.

Each term in the above expression lends itself to intuitive interpretation. The first term ( $\sigma_i^x \epsilon \hat{P}_i$ ) represents the location response and shows that employment will be reduced in proportion to the product of the export share, the elasticity of the location response, and the percentage change in regional production costs. The second term ( $\hat{\ell}_i$ ) represents the labor substitution term and measures how employment will be changed as labor intensity changes. The third term ( $-(1 - \sigma_i^x)(1 - D_i) \hat{Y}_i$ ) represents the intermediate input substitution term and indicates that employment will change as local intermediate users substitute other inputs for intermediate inputs that have increased in price.

If the feedback effect of change in capital and labor costs in the  $i^{\text{th}}$  industry and intermediate input costs are ignored, it is possible to express  $\hat{P}_i$ ,  $\hat{\ell}_i$  and  $\hat{Y}_i$  as

<sup>9</sup>The source of these series is given as follows: The regional purchase coefficients for manufacturing were estimated from shipment data and equations (20) and (22), the regional purchase coefficients for non-manufacturing were estimated by finding the highest value that would insure exports greater than zero during the sample period, with a maximum value of 1.00. The proportion of export dependent employment was obtained by dividing total employment less the employment explained in equation (2) by total employment. The labor share and capital share were obtained from the input shares in the national input-output table.

<sup>10</sup>Obtained by substituting equations (9), (8), (2), (15), (18), (19), and (26) into equation (1).

functions of the percentage change in capital costs ( $\hat{c}_i$ ) and labor costs ( $\hat{w}_i$ ). Thus, by differentiating equations (27), (14) and (A-14), performing the relevant substitution and collecting terms, it is possible to obtain the following expression that relates the percentage change in employment to the percentage change in capital and labor costs, holding other input prices constant.

$$\begin{aligned} \hat{E}_i = & \sigma_i^x \epsilon \lambda_{Li} \hat{w}_i + (\lambda_{Li} - 1) \hat{w}_i - \rho_i (1 - \sigma_i^x) (1 - D_i) \lambda_{Li} \hat{w}_i \\ & + \sigma_i^x \epsilon \lambda_{Ki} \hat{c}_i + \lambda_{Ki} \hat{c}_i - \rho_i (1 - \sigma_i^x) (1 - D_i) \lambda_{Ki} \hat{c}_i \end{aligned} \quad (29)$$

It is easy to see that the direct partial equilibrium effect of any increase in labor cost will be to decrease regional employment because all of the terms involving  $\hat{w}_i$  are negative. These terms show the negative location effect ( $\epsilon < 0$ ), the negative factor substitution effect ( $\lambda_{Li} < 1$ ) and the negative intermediate input substitution effect. However, when capital costs are increased the labor substitution effect is positive. Therefore, an increase in capital costs in a region will decrease employment only if:

$$|\sigma_i^x \epsilon - \rho_i (1 - \sigma_i^x) (1 - D_i)| > 1. \quad (30)$$

This means that if the elasticity of location and intermediate input substitution is greater than unity in absolute value the employment-increasing effects of increasing capital costs will be offset by reductions in regional production.<sup>11</sup>

Since taxes are the main policy instruments that affect wage and capital costs, it is useful to calculate how changes in various tax rates affect capital or wage costs. These are given in Table 2 and indicate that rather modest changes in tax rates can have a substantial impact upon regional factor cost differentials.

Using Tables 1 and 2 and equation (29) the reader can calculate the direct employment effect of each tax change shown in Table 2. For example, the partial equilibrium percentage increase in employment that would result from eliminating the 9.5 percent corporate profits tax in Massachusetts would be a 2.5 percent increase in employment in the electrical machinery sector and a 0.2 percent increase in the service and miscellaneous sector.

<sup>11</sup> See also Borts and Stein (1964) and McNertney (1977)

Table 2

The Impact of Tax Changes on Massachusetts Factor Costs  
Relative to U.S. Factor Costs

Tax Rate	Change	Affected Factor Cost	% Change Manufacturing	% Change Non-Manufacturing
State Corporate Profits Tax	9.5% to 0%	Capital	-5.5	-5.4 <sup>12</sup>
State Corporate Profits Tax	9.5% to 8.5%	Capital	- .6	- .6 <sup>12</sup>
State Equipment & Inventory Tax	.23% to 0.0%	Capital	- .8	- .6
Local Property Tax	3.5% to 0.0%	Capital	-5.9	-8.0
State Manufacturing Equipment Investment Tax Credit	3.0% to 0.0%	Capital	+1.3	0.0
Federal Profits Tax	48.0% to 0.0%	Capital	+ .2	+ .6
Federal Investment Tax Credit	9.9% to 0.0%	Capital	+ .2	+ .2
Unemployment Insurance Tax	1.7% to 0.0%	Labor	-1.7	-1.7

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<sup>12</sup> Except for those sectors exempted from the corporate profits tax.

#### IV. The Employment Effects of Tax Changes in a Closed Regional Model

Since the employment effects generated by equation (29) do not consider the linkages between employment and income, they do not capture the full impacts of factor price changes upon regional employment. Thus a complete simultaneous regional model is needed to examine the total effects of any tax changes upon regional employment. On the demand side, this model incorporates the linkage between employment, income, and final demand; on the supply side, the linkage between factors affecting labor supply and wages.

While a great many equations are required to complete the model, most of them are straightforward accounting relationships that need not be dealt with in detail.<sup>13</sup> Thus, employment and wages are used to determine regional incomes. Personal taxes are a function of incomes and are subtracted to obtain personal disposable income. In the regional consumer price determination equation, the regional prices ( $y$ 's) and consumer taxes are given their appropriate weights.

Local government demand is related to personal income and to the percentage of the population in primary and secondary school. In the policy simulations, state government demand is determined by the need to maintain the real per capital level of government services. State welfare payments are based on the population which is not employed. Government employment is related to real government spending and the welfare case load.

The investment demand equations are derived from the theoretical framework set forth above, only in this case, capital demand is estimated instead of employment demand. The speed of adjustment of the actual to the equilibrium capital stock was estimated by regression.

The wage determination equation for the region relative to the nation is based on relative labor supply. Thus, wages respond with an elasticity of .87 when personal or consumer taxes reduce real disposable income per dollar of personal income in the region relative to the nation. Similarly wages respond with an elasticity of .49 when the ratio of

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<sup>13</sup>See Treyz et al (1977) for the complete specification.

employment to the over 18 population increases in the region relative to the nation.

This model can be used for policy analysis by comparing the projected values of the relevant endogenous variables under a control forecast with their values under a specific policy scenario that alters input costs. Its application is illustrated by the analysis of a package that eliminates the Massachusetts 3 percent manufacturing equipment tax credit while reducing the Massachusetts corporate profits tax sufficiently to offset the gain in revenues due to the elimination of this tax credit. This simulation is, in effect, a balanced budget incidence analysis in which the Massachusetts corporate tax rate is treated as the endogenously adjusting tax parameter. A rate reduction from 9.5 percent to 8.6 percent was found to yield this budget balance.

The effects of the tax package on costs, prices, wages, incomes and construction are shown in Table 3, the employment effects are shown in Table 4. The employment effects are virtually nil in the first year but grow to a negative effect of one-tenth of one percent or a net loss of almost 3,000 jobs by the fourth year of the simulation.

In the first year business costs increase .131 percent in manufacturing due to the relative size of the changes and due to the difference in the way in which the credit and the tax enter into the cost of capital (See equation A-7 in the Appendix). Non-manufacturing business costs are unaffected by the cut in the tax credit and thus decrease by .041 percent due to the profits tax cut. The net effect of these manufacturing and non-manufacturing business cost changes is to reduce the Boston Consumer Price Index because locally-produced non-manufacturing services are a much larger percent of consumer expenditures than are locally-produced manufacturing goods. The wage index is reduced very slightly due to the effect of lower prices on labor supply. Real, per capita, disposable income is increased slightly by the drop in the price index in the face of unchanged nominal income.

The corporate profits tax cut decreases the cost of structures relative to other factor inputs. This decrease leads to sufficient substitution of structures for other inputs to increase non-residential construction. However, the increased cost of manufacturing equipment due to the elimination of the tax credit operating

through both the substitution effect and through negative effects on business location, is more than enough to offset the positive effects of the cut in the cost of structures on investment in manufacturing plant and equipment. Table 4 shows that all manufacturing employment, except furniture which is an input into construction investment, suffers losses. On the other hand, higher construction and slightly higher real incomes lead to increased employment in non-manufacturing.

In the second year the negative location effect shows up in all four quarters and begins to dominate through its effect on manufacturing employment. This reduces real disposable incomes as wage reductions are added to employment cuts. In the second year, only construction shows positive employment effects as the positive substitution effect of reduced costs for structures still dominates the negative location effect of manufacturing business moving out of the state.

By the fourth year of the simulation, the reduction in wages due to both lower prices and to weaker labor markets begins to mitigate the increase in manufacturing costs from the investment credit tax change and to increase the reduction in non-manufacturing business costs. Nevertheless, by 1980, the total reduction in real incomes and state economic activity is great enough to lead to reduced employment in all non-manufacturing sectors. The negative location effect on manufacturing employment affects every sector. Since the location effect is fully realized in five years this effect will reach its peak in the second quarter of 1981. The substitution of labor for capital due to the increase in equipment costs and the cut in labor costs will continue for 13 years after the relative prices have stabilized.

#### V. Summary and Conclusions

The model developed in this paper reflects the interindustry structure of the region and determines factor intensities and industrial location. The latter respond to changes in endogenous cost variables and the direct and indirect effects of regional and national policy instruments. The use of the model for Massachusetts is demonstrated by a simulation based on a reduction of the manufacturing equipment investment tax

Table 3

The Effects of a Tax Package Consisting of:  
(1) Reducing the Corporation Profits Tax Rate from 9.5% to 8.6% and  
(2) Eliminating the 3% Manufacturing Equipment Investment Tax Credit

Selected Variables from the  
Massachusetts Economic Policy Analysis Model  
(Percent Differences from Control Forecast)

	1977	1978	1979	1980
Rel. Business Cost Index	.012	.007	-.006	-.020
Manufacturing	.131	.128	.118	.106
Non-manufacturing	-.041	-.047	-.061	-.076
Boston C.P.I.	-.012	-.018	-.028	-.040
Fixed Weight Wage Index	-.001	-.030	-.034	-.059
Personal Income	-.000	-.030	-.068	-.107
Disposable Income	-.000	-.029	-.067	-.105
Real Per Cap. Disposable Income	.011	-.006	-.026	-.045
Non-Resid. Construction	.549	.311	.086	-.061
Mfg. Plant & Equip. Investment	-.052	-.222	-.372	-.493

Table 4

The Effects of a Tax Package Consisting of:

- (1) Reducing the Corporation Profits Tax Rate From 9.5% to 8.6% and
- (2) Eliminating the 3% Manufacturing Equipment Investment Tax Credit

Employment in Massachusetts  
(Per Cent Differences from Control Forecast)

	1977	1978	1979	1980
Manufacturing	-.026	-.113	-.197	-.272
Durables	-.030	-.125	-.215	-.295
Ordnance (19)	-.036	-.133	-.226	-.311
Lumber (24)	-.020	-.124	-.230	-.329
Furniture (25)	.009	-.069	-.144	-.209
Stone, Clay, etc. (32)	-.000	-.077	-.157	-.227
Primary Metals (33)	-.031	-.126	-.217	-.299
Fabricated Metals (34)	-.019	-.096	-.169	-.234
Non-elec. Machinery (35)	-.031	-.123	-.209	-.284
Elec. Equipment (36)	-.032	-.119	-.200	-.272
Transport. Equipment (37)	-.029	-.120	-.205	-.281
Instruments (38)	-.047	-.194	-.337	-.469
Nondurables	-.021	-.099	-.174	-.242
Food (20)	-.002	-.038	-.074	-.106
Textiles (22)	-.024	-.098	-.169	-.232
Apparel (23)	-.015	-.072	-.127	-.174
Paper (26)	-.024	-.107	-.189	-.262
Printing (27)	-.017	-.086	-.153	-.212
Chemicals (28)	-.037	-.150	-.259	-.360
Rubber (30)	-.026	-.111	-.193	-.267
Leather (31)	-.032	-.134	-.232	-.322
Other Nondurables (39)	-.028	-.132	-.234	-.326
Nonmanufacturing	.014	-.008	-.032	-.053
Contract Construction	.089	.048	-.014	-.064
Transport & Utilities	.008	-.020	-.051	-.078
Wholesale & Retail Trade	.016	-.012	-.043	-.070
Finance, Insurance, etc.	.011	-.013	-.040	-.064
Services & Miscellaneous	.009	-.009	-.029	-.044
Government	.004	-.005	-.016	-.027
Federal	.000	.000	.000	.000
State	-.001	-.002	-.003	-.004
Local	.007	-.007	-.025	-.042
Nonag. Wage & Sal. Employ.	.004	-.035	-.076	-.112

credit with the revenue gain absorbed by a decrease in the corporate profits tax.

This policy had a negative effect on Massachusetts employment.

The need for a regional dimension to national stabilization policies is obvious. Unfortunately, regional input-output models contain such rigidities that the use of a system of such models for economic policy purposes has limited applicability; on the other hand regional econometric modeling efforts have often been based on ad hoc regression equations and thus, may be unsatisfactory as elements in a national system of simultaneous regional models. The model presented here represents a consistent theoretical structure based on an explicit set of assumptions and could be applied to any region. Such applications would be interesting, not only as a way to examine regional differences in responses to policy changes, but also as a step toward an interactive system of regional structural models that could be used in the formulation and implementation of national economic policy.

APPENDIX

THE DERIVATION OF REGIONAL INPUT COSTS

Since regional employment is sensitive to relative input prices it is important to ensure that these prices reflect regional taxes and other relevant policy variables. Thus this appendix describes the derivation of the regional input prices used in this model.

A. Capital Costs

The derivation of the implicit rental cost of capital is adapted from Hall and Jorgenson (1967) and includes the impact of different taxes on different levels of investment.

Let  $c_t^*$  reflect the cost of capital service in period  $t$  and  $c_t'$  reflect the after-tax cost of capital service in time  $t$ . Then:

$$c_t' = c_t^* - T_{ft}' - T_{st} - T_{Pt} \quad (A-1)$$

where  $T_{ft}$  and  $T_{st}$  respectively represent federal and State profits taxes, and  $T_{Pt}$  represents local property taxes.

Federal profits tax collections can be represented by the following expression which is based upon Hall and Jorgenson (1967):

$$T_{ft} = \tau_{ft}(c_t^* - T_{st}' - T_{et} - D_t(1-AI_{ft})y_o - R_t y_o B_t - T_{Pt}) - I_{ft}y_o \quad (A-2)$$

where

$\tau_{ft}$  = the federal corporate profits tax rate;

$c_t^*$  = the cost of capital services in period  $t$ ;

$T_{st}$  = State profits tax payment;

$T_{et}$  = State equipment tax payment;

$D_t$  = the depreciation allowed for federal taxes in period  $t$ ;

$A_t$  = a dummy variable to reflect the impact of the Long Amendment equal to 0 when the Long Amendment is in effect and 1 otherwise;

$I_{ft}$  = the value of the federal Investment tax credit;

$y_o$  = the initial purchase price of the equipment;

$B_t$  = the proportion of business capital financed by bonds and loans;

$R_t$  = the interest rate.

The equation for the regional profits tax is analogous and takes the following form:

$$T_{st} = \tau_{st}(c_t^* - D_t(1 - AI_{ft})y_o - Fy_o B_t - T_{Pt}) - I_{st}y_o \quad (A-3)$$

where  $I_{st}$  denotes the State tax credit and the other variables have been defined in Equation (A-2) .

Massachusetts not only has a State tax on corporate income but also has a tax on equipment, which is typically not subject to local property tax. Thus:

$$T_{et} = \tau_{et} y_o \quad (A-4)$$

where  $\tau_{et}$  represents the rate and  $y_o$  represents the purchase price of the equipment.

Substituting Equations (A-2) - (A-4) into (A-1) and collecting terms yields:

$$\begin{aligned} c_t' = & (1 - \tau_{ft} + \tau_{ft}\tau_{st} - \tau_{st})c_t^* - (\tau_{ft}\tau_{st} - \tau_{ft} - \tau_{st})D_t(1 - AI_{ft})y_o \\ & - (\tau_{ft}\tau_{st} - \tau_{ft} - \tau_{st})R_t y_o B_t - (1 - \tau_{ft} + \tau_{ft}\tau_{st} - \tau_{st})\tau_{Pt} \\ & + (1 - \tau_{st})I_{st}y_o + I_{ft}y_o \end{aligned} \quad (A-5)$$

In equilibrium, the firm will equate the present value of the net returns from the investment to its purchase price. Thus:

$$q_o = \int_0^{\infty} e^{-(R_r + \delta)t} c_t' dt \quad (A-6)$$

where  $\delta$  represents the rate of economic depreciation. Substituting Equation (A-5) into (A-6), performing the integration under static price expectations dividing through by  $y_o$  and solving for  $c_t'/y_o$ , we find:

$$\begin{aligned}
\frac{c'_t}{y_o} = & (R_t + \delta)B_t + \frac{(R_t + \delta)(1-B_t)}{(1-\tau_{ft})(1-\tau_{st})} + \\
& + \frac{(R_t + \delta)(\tau_{st}\tau_{ft} - \tau_{ft}) Z_t (1-AI_{ft}) - I_{ft}}{(1-\tau_{ft})(1-\tau_{st})} \\
& + T_{pt} + \frac{(R_t + \delta)I_{st}}{(1-\tau_{st})} \quad (A-7)
\end{aligned}$$

where  $Z_t$  represents the discounted value of the depreciation exemption and is defined as

$$Z_t = \int_0^{\infty} D_t e^{-(R_t + \delta)t} dt \quad (A-8)$$

Since Massachusetts at one time instituted a 5-year new equipment exemption the State equipment tax, this must be taken into account. Write:

$$\frac{T_{et}}{y_o} = \int_0^L e^{-(R_t + \delta)t} \tau_{et} dt - \int_0^5 e^{-(R_t + \delta)t} \tau_{et} dt \quad (A-9)$$

where  $L$  reflects the life of the equipment and equals  $(1/\delta)_{eq}$ . Thus the first term of Equation (A-9) reflects the discounted value of the tax payments over the equipment's life, while the second term denotes the value of the exemption. Solving for  $T_{et}$  when the equipment exemption is in force:

$$T_{et} = (e^{-5(R_t + \delta)} - e^{-L(R_t + \delta)}) y_o \quad (A-10)$$

Thus,  $T_{et}$  is defined by Equation (A-10) when the equipment exemption is in force.

By making the appropriate adjustments, expressions for the cost of capital in equipment, inventory and structures for both the State and the nation as a whole can be obtained. Thus the expressions for the relative cost of capital in industry  $i$  is given by:

$$\frac{c_i}{c_i^u} = \left( \frac{c_{eq}}{c_{eq}^u} \right)^{\xi_{eqi}} \left( \frac{c_{inv}}{c_{inv}^u} \right)^{\xi_{invi}} \left( \frac{c_{str}}{c_{str}^u} \right)^{\xi_{stri}} \quad (A-11)$$

where eq, inv, and str respectively denote equipment, inventory and structure, and  $\xi_{eqi}$ ,  $\xi_{invi}$ , and  $\xi_{stri}$  denote the share of total, investment in industry i allocated to equipment, inventories, and structures, respectively, and were estimated to be 0.52, 0.34, 0.14 for manufacturing and 0.47, 0.07, 0.47 for non-manufacturing. The values of depreciation for equipment ( $\delta_{eq}$ ), structures ( $\delta_{str}$ ) and inventory ( $\delta_{inv}$ ) were respectively estimated to be 1/13, 1/35, and 0 respectively.

### B. Labor Costs

The derivation of the labor costs is straightforward and is given by:

$$w_i = w_i' + T_{wi} \quad (A-12)$$

where

$w_i$  = the average hourly laborcosts in industry i;

$w_i'$  = the average hourly wage in industry i;

$T_{wi}$  = the average unemployment taxes in industry i, expressed in hourly terms.

### C. Energy Costs

Energy costs are divided into electricity and other costs as:

$$\left( \frac{f_i}{f_u} \right) = \left( \frac{f_{ei}}{f_{ei}} \right)^{\xi_{ei}} \left( \frac{f_{oi}}{f_{oi}} \right)^{\xi_{oi}} \quad (A-13)$$

where  $f_{ei}$  and  $f_{ei}^u$  respectively represent the average costs per kilowatt hour for electricity in industry i in the region and the nation;<sup>1</sup>  $f_{oi}$  and  $f_{oi}^u$  respectively represent the average cost for other energy sources in the region and the nation; and  $\xi_{ei}$  and  $\xi_{oi}$  respectively represent the share of the fuel bill in industry i that goes for electricity and other energy sources.

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<sup>1</sup>Note that i simply ranges over the manufacturing and non-manufacturing industries.

#### D. Materials Costs

Data are not available for regional materials input prices. Therefore, the regional purchase coefficient is used to apportion the materials input used in the region between that produced in the region and that produced elsewhere. Then it is assumed that the ratio between the price of the material input produced locally and the national price is in the same ratio as the ratio of production costs. (See equation 28).

Thus,

$$y_i = (1-\rho_i) + \rho_i P_i' \quad (A-14)$$

The first period values for the sample period were found using an iterative procedure that yielded a set of  $y$ 's that were simultaneously consistent. For all other periods

$y_{it}$  was derived as

$$y_{it} = (1-\rho_i) + \rho_i P_{it-1}' \quad (A-15)$$

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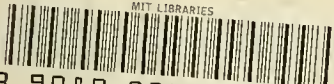
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